DEVELOPMENT OF AUTOMATIC POWER FACTOR CORRECTION DEVICE

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ABSTRACT

Nowadays the life cost more getting higher and higher. People more consider every dollar that they spend in their daily life. The price of gasoline more getting higher every year, this also make the life cost for each family increase. The price of electricity also increases because of the increase gasoline price. The people should spend their money with efficiently to make sure that the money that they spend is totally useful. There have two methods to save the electricity usage; the first one is using the electricity energy with smart, for example when the air-conditioner is not used it should turn off. The second is using the power factor correction technique, but this method just for inductive load such as air-conditioner, washing machine and refrigerator. The inductive load running causes the leading power factor, means the current that used is more and not totally used. To overcome this problem the reactive component is added, the capacitor is added to improve the power factor and also reduce the current that transfer to the inductive load. The microcontroller (PIC) is use as a control element that switching the capacitor to the power line. The sensor is place at the power line to giving the signal to the microcontroller, microcontroller analyze the signal that feed from the sensor. Microcontroller execute the instruction depend to the signal that giving.

ABSTRAK

Pada setiap tahun taraf hidup semakin meningkat dan setiap orang mengira setiap ringgit yang mereka belanjakan. Pada setiap tahun juga harga bahan api terutamanya petrol meningkat berikutan perminataan yang tinggi oleh setiap Negara. Ini menyebabkan tarif elektrik meningkat berikutan meningkatnya harga bahan api di pasaran. Setiap orang perlu menggunakan duit mereka dengan bijaknya bagi menanpung perbelanjaan sara hidup yang makin meningkat. Bagi mengurangkan beban yg ade mereka seharusnya menggunakan elektrik dengan sebaiknya. Ada dua kaedah untuk menjumatkan penggunaan elektrik, salas satunya ialah menggunakan elektrik dengan jimat cermat sebagai contoh apabila tmeninggalkan bilik penyaman udara dan perkakas elektrik yang lain seharusnya dimatikan. Keadah ini berkesan bagi menjimatkan elektrik tetapi penggunaan elektrik masih tidak efisyen. Kaedah kedua adalah menggunakan teknik pembetulan faktor kuasa, tetapi kaedah ini hanya berkesan bagi alat yang mengunakkan applikasi moto. Apabila alat berplikasi moto bekerja faktor kuasa dalam talian kuasa menjadi rendah iaitu mengekori. Bagi membetulkan balik komponent reaktif diperlukan, kapasitor adalah komponent reaktif digunakan bagi membetulkan balik faktor kuasa. Pemprosesan Kawalan Mikro (PIC) digunakan bagi mengawal kemasukan kapasitor dalam talian. Kemasukan kapasitor bergantung kepada masukan data daripada peranti pengesan. Ini mengelakan daripada faktor kuasa mendahui daripada terjadi.

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LIST OF ABBREVIATIONS

AC	–	Alternate Current
ADC	–	Analog to Digital Converter
DC	–	Direct Current
APFC	–	Automatic Power Factor Correction
Vac	–	Voltage alternate Current
LED	–	Light Emitting Diode
LCD	–	Liquid Crystal Display
PIC	–	Programmable Intelligent Computer
Vdc	–	Voltage Direct Current
TNB	–	Tenaga Nasional Berhad
VAR	–	Unit of Appearent Power
V_o	–	Output Voltage

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CHAPTER 1

INTRODUCTION

1.1. Project Background

In the recent year the life cost is getting more expensive and the people need to consider all the money that they spend. The electric tariff from TNB getting higher in every year because the electric tariff, depend to the price of gasoline. The electricity bills is the one of the life cost that need to support because without electric people can't do their daily life. To minimize the electric bill in the manual method is try to use the electric with the smart. The other method to minimize the electric bill is used the automatic power factor correction (power saver).

This project is focus on the design and building a unit of automatic power factor correction, this device more suitable and effective in the house that used a lot of inductive component such as air-conditioner, washing machine and etc. This device is function as the power factor corrector to improve the power factor to unity. The value of capacitor that insert in the system is depend to the value of power factor that control by microcontroller.

The problems of this we have to determine the value of the power factor and the value of the capacitor that we need to insert in the system. The value of the

capacitor is the most important because it will change the power factor to unity and significantly the current to the load is reduce. This is the main problem we have to focus because it will determine the percentage of the save the electricity.

1.2. Objectives:

The objectives of this project are:

I. Develop automatic power factor correction (power saver)
II. This device able to reduce the power consumption in the house and minimize the electricity cost.
III. To help the people reduce the life cost by reduce the electricity cost.

1.3. Scope of Project

The scope of this project can be summarizing as follows:

I. This projects focus on the single-phase system 240Vac, for house application.
II. The maximum current rating is 40A, suitable for house that usually current rating is same.
III. Device use 4 parallel capacitors to improve power factor.
IV.

1.4. Literature Review

The power factor of an AC electric power system is defined as the ratio of the real power to the apparent power, and is a number between 0 and 1. Real power is the capacity of the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, the apparent power can be greater than the real power. Low-power-factor loads increase losses in a power distribution system and result in increased energy costs [1].

The significance of power factor lies in the fact that utility companies supply customers with volt-amperes, but bill them for watts. Power factors below 1.0 require a utility to generate more than the minimum volt-amperes necessary to supply the real power (watts). This increases generation and transmission costs. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor, so the losses in the circuit would be doubled (since they are proportional to the square of the current). Alternatively all components of the system such as generators, conductors, transformers, and switchgear would be increased in size (and cost) to carry the extra current [2].

Interfacing the microprocessor with the AC power lines need to consider the voltage, current and also power dissipated by the microcontroller (PIC). The PIC chip only support 1W power dissipation [1]. The phase voltage and current is detected using the current and voltage transducer. Using the external existing unique function (zero crossing detector) in PIC16F77 the phase shift between voltage and current is determine [1]. High external resistor must be connect place before connect to input circuit, to ensure that PIC not damage. PIC 16C5X series is design to short the input when the large voltage is applied to protect the chip from static electric short [3].

The Hall Effect sensor is the one device that used to interface between the power line and the microcontroller (PIC) [4]. This sensor is connecting series with the inductive load. It has an internal current transducer that senses the electromagnetic field. It also produce the output voltage that suitable for the PIC (0V-5V), this output voltage is in AC because use in the AC application, it also suitable use in DC application. This device precise is depending to the temperature, it sense the fully scale current at the 25^{o}C [4].

1.5. Report Outline

This report is divided into six chapters. Chapter 1 is explaining about the background of the project, objectives, scope of project and literature review. Chapter 2 explaining about the power factor, phase and phasor diagram, automatic power factor correction, current sense conventional APFC and summary for this chapter. The new automatic power factor correction device (power saver) should have ability to reduce the power factor to unity when the inductive component exists in the system. This device should have a correct trigger the step of the capacitor to accomplish the value VAR in the system and the current transfer to load is less. Chapter 3 explain about the control element circuit, the PIC 18F4550 is used as a brain of the system, this microcontroller PIC is used to monitor all the changing current in the system that feed by the current sensor. The porta is used to feed the input because only porta have the special features that can receive analog input. The oscillator is the important thing that generates the frequency when the voltage is given. The frequency generate is feed to the microcontroller and as a clock for microcontroller to function. Microcode studio is used to write and compile. It convert pbp file to the hex file. The PICkit is used to burn the program to the microcontroller, the hex file is transfer to the PICkit program and it transfer into microcontroller. Chapter 4 explains about methodology of the project. The power factors is study fist and also find the technique to improve the power factor. The purpose design for this project is using the current sensor as the input and the driver

relay circuit as an output. The current sensor is feed the signal to the microcontroller, the microcontroller analyze and give the output to the driver relay circuit according the condition that stated in the programming. Chapter five explain about the result and discussion, the result of the power factor is determined using the motor load. There have two type of motor used, first is 600W motor, the current 0.3A are reduce after the APFC operate. The initial power factor is 0.83pf and after insert the capacitor insert the power factor become 0.92pf. Second is 1.32KW motor, current 0.5A are reduce after APFC operate. The initial power factor is 0.77pf and after insert capacitor the current is 0.83pf. Chapter 6 explains about the conclusion and suggestion. This device is able to reduce the current usage by the inductive load.

CHAPTER 2

AUTOMATC POWER FACTOR CORRECTION (APFC)

2.1. Introduction

Power factor is the ratio of true power or watts to apparent power or volt amps. They are identical only when current and voltage are in phase then the power factor is 1.0. The power in an ac circuit is very seldom equal to the direct product of the volts and amperes. In order to find the power of a single phase ac circuit the product of volts and amperes must be multiplied by the power factor. Ammeters and voltmeters indicate the effective value of amps and volts. True power or watts can be measured with a wattmeter. If the true power is 1870 watts and the volt amp reading is 2200. Than the power factor is 0.85 or 85 percent. Real power divided by apparent power. The power factor is expressed in decimal or percentage. Thus power factors of 0.8 are the same as 80 percent. Low power factor is usually associated with motors and transformers. An incandescent bulb would have a power factor of close to 1.0. A one hp motor has power factor about 0.80. With low power factor loads, the current flowing through electrical system components is higher than necessary to do the required work. These results in excess heating, which can damage or shorten the life of equipment, a low power factor can also cause low-voltage conditions, resulting in dimming of lights and sluggish motor operation.

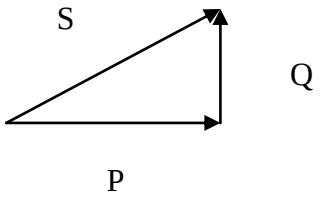
Low power factor is usually not that much of a problem in residential

homes. It does however become a problem in industry where multiple large motors are used. So there is a requirement to correct the power factor in industries. Generally the power factor correction capacitors are used to try to correct this problem.

For a DC circuit the power is P=VI and this relationship also holds for the instantaneous power in an AC circuit. However, the average power in an AC circuit expressed in terms of the rms voltage and current is

$$P_{avg} = VI \cos\varphi$$

Where, φ is the phase angle between the voltage and current. The additional term is called the power factor. Power factor triangle is shown in Figure 2.1.



Power Factor = P/S

Figure 2.1: Power Factor triangle

From the phasor diagram for AC impedance, it can be seen that the power factor is P/S. For a purely resistive AC circuit, P=S and the power factor = 1.

2.2. Phase and Phasor Diagram

When capacitors or inductors are involved in an AC circuit, the current and voltage do not peak at the same time. The fraction of a period difference between the peaks expressed in degrees is said to be the phase difference. The phase difference is <= 90 degrees. It is customary to use the angle by which the voltage leads the current. This leads to a positive phase for inductive circuits since current

lags the voltage in an inductive circuit. The phase is negative for a capacitive circuit since the current leads the voltage. Figure 2.2 shows the waveform for voltage and current when the power factor is leading. The current lead the voltage because the inductive component running.

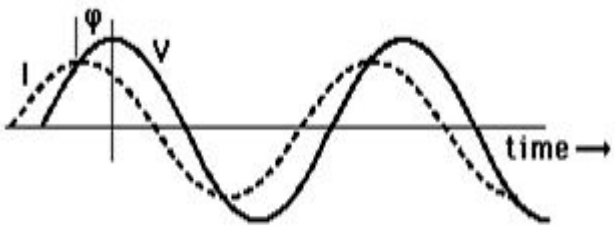


Figure 2.2: Phase Diagram for leading PF

2.3 Automatic Power Factor Correction

An automatic power factor correction (APFC) is a device that used to improve the power factor to unity using the microcontroller. Usually the automatic power factor correction is used in the industry such as the factory that used the biggest horse power (hp) motor. Such as the chiller system, chiller system is the one of the type air-conditioner. This chiller used the motor to operate; motor is used as pump to pump the water for each floor in the building. The motors that used have 200hp each to pump the water in each floor. This motor is operate when the temperature high inside the building and off when the temperature reach at the desire level. The automatic power factor correction is needed here because to maintain the value of the power factor unity. The value of power factor unity is important because it will affect the current and voltage drop in the system. Second is TNB will give the penalty if the power factor below that 0.8, power factor below that 0.8 need to supply more energy to this system and make them loss out. This device is function to monitor the system that makes sure that the value of the power factor approach to unity.

2.4 Operation of APFC

The automatic power factor correction is the device the used the microcontroller to analyze the power factor in the system. The microcontroller is the brain of the system because where the power factor is analyze and determine the value. Microprocessor receives the signal from the voltage and current transducer. Microprocessor is build in the analog digital converter, This ADC is used to convert analog signal to the digital signal, the digital signal from the current and voltage transducer is analyze. To determine the power factor zero-crossing detector is used. The programming of microprocessor is the most important because, if the inductive components running the voltage are lagging current. The signal from the current transducer will on the timer and the signal from voltage off the timer, from the delay between the current and voltage the power factor is determine. Figure 2.3 show the time delay between current and voltage.

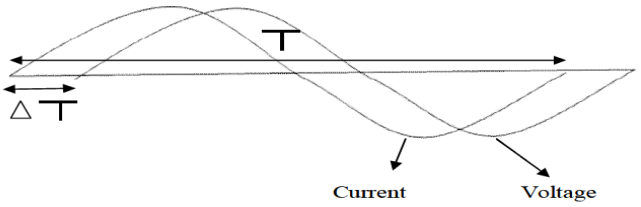


Figure 2.3: Waveform voltage and current

The value of capacitor is depends to the value of the VAR that used in the system (motors). The microprocessor will give the signal the contactor to turn on capacitor to the system depend to the value of VAR that used. The steps of the capacitor usually for the system is depend to the how many the inductive component (VAR) in the system. That means before the automatic power factor is design the value of the VAR in system need to know first and the how many steps of the capacitor will determine. The figure 3.2 shows the block diagram for the system.

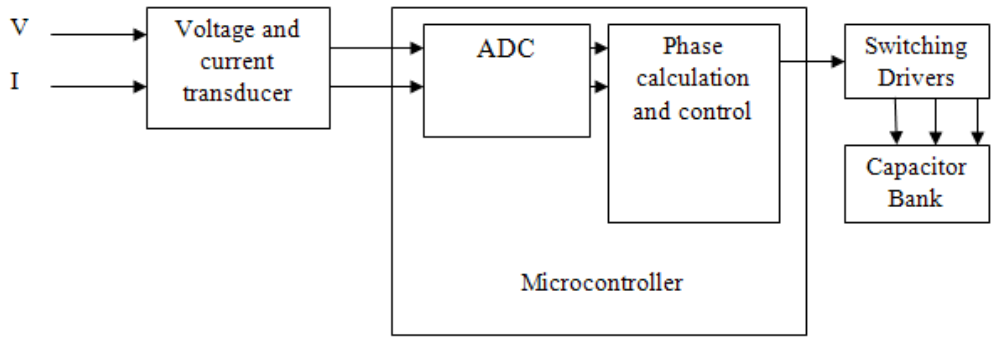


Figure 2.4: Block diagram Power factor Controller

2.5 APFC Design

There are two circuits for design automatic power factor correction. First is control circuit that consists of microcontroller, two transducers and driver relays. Second is power circuit that consists of capacitor bank and relay.

2.5.1 Relay

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In the original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. Because a relay is able to control an output circuit of higher power than the input circuit, it can be considered, in a broad sense, to be a form of an electrical amplifier. Current flowing

through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. Usually this is a spring, but gravity is also used commonly in industrial motor starters. Most relays are manufactured to operate quickly. In a low voltage application, it is used to reduce noise. In a high voltage or high current application, it is used to reduce arcing. The symbol circuit of relay and the relay are shown in Figure

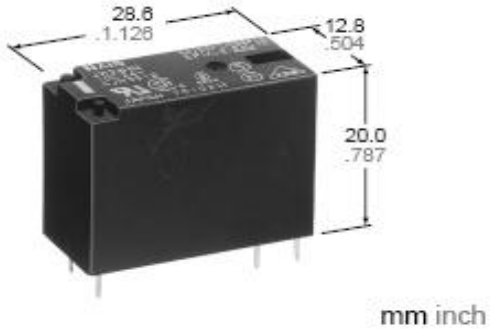


Figure 2.5: Relay

2.5.2 Current Transducer

There are several types of current detector such as current transducer, transtronics current detector and current transformer which are use for detected current by sensing the AC current. This device is function when the wire carrying the current through the coil. The magnetic field form from the wire will detect, the coil consist in the current transducer will induce the current, acting like transformer. Figure 3.4 below the current transducer. The application of current transducer normally use in sensing overload current, ground fault detection, metering and analog to digital circuit.